A Novel Transmission Line Model for Analyzing Bowtie Patch Antennas

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Abstract—A novel transmission line model is represented to model bowtie patch antennas. The purposed model uses two slots for modeling the radiation from patch sides. Each radiation slot is presented by parallel equivalent admittance. Also in this model mutual coupling and the effect of slots length limitation as well as the influence of the side slots on the radiation conductance are taken into account implicitly. Admittance and controlled source equations that used for rectangular patch antenna are modified.

1. Introduction

These days microstrip antennas are popular and getting more and more attention due to their excellent advantages. Depending upon the applications, microstip antennas having different geometrical shapes are used. In other hand now days researchers are interested in the design and development of compact microstip radiating elements. It can be argued that Bowtie microstip antenna is one of such compact microstrip antennas [2]. The Bowtie antenna dose not has a regular geometric shape and hence most of the analytical techniques such cavity model can not be used for antenna's parameter calculation directly. However, popular numerical techniques like method of moment (MOM), finite element method, finite-difference time -domain (FDTD) method, etc., could be used for analysis of such antennas but they are computationally expensive.

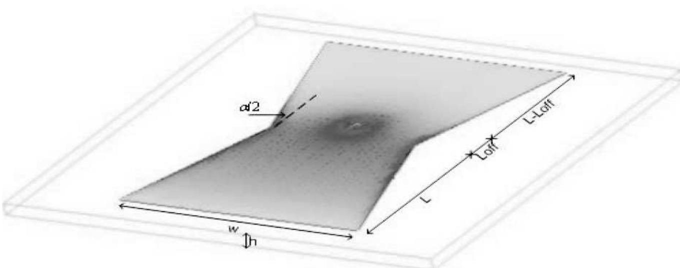

Figure 1: Antenna structure.

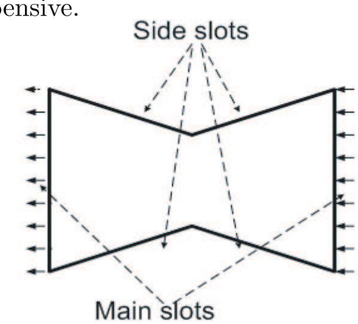

Figure 2:

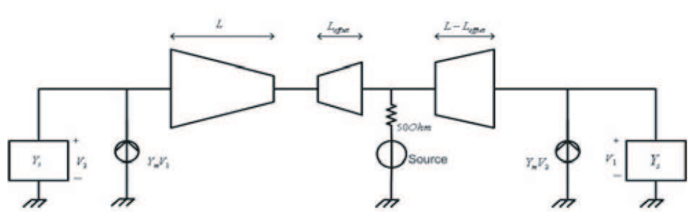

Figure 3: Antenna structure.

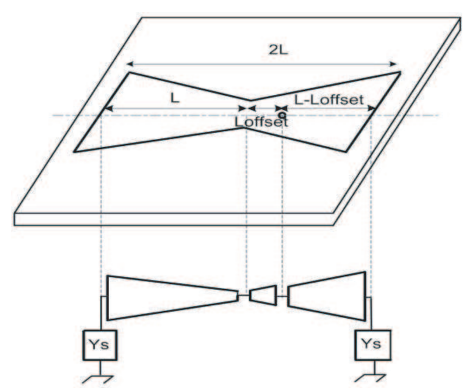

Figure 4:

The transmission line method (TLM) is known to be reasonably accurate and have good efficiency especially in numerical calculation as well as it can be applied for modeling of antennas arrays. Therefore in this paper a novel transmission line model is presented for analysis of bowtie patch antenna of finite length, placed on a dielectric substrate as shown in Fig. 1. Also Fig. 2 shows the radiating slots which form a useful model for calculating the radiation filed of the antenna. These so-called equivalent slots consist of two main slots with a uniform distribution and four side slots with sinusoidal distribution.

In order to model regular microstrip antenna with the existing transmission-line models, shape of the antenna represented by a line section terminated at both ends by radiation admittance. Also an improved TLM model for rectangular microstip antenna has been introduced by Pues abd Van de Cappelle which used voltage dependent current generators for modeling mutual coupling [1].

Our model in this paper is similar to Pues model [1] in addition we have used taper transmission line instead normal microstrip line for modeling bowtie shaped patch as shown in Fig. 3. More over as can be seen in Fig. 3 the offset of feed location has been considered by dividing the taper line into two sections.

2. Determination of Model Parameters

Figure 4 model contains of following unknowns:

1. The line parameters (Y_c).
2. The self admittance of slots (Y_s).
3. The mutual admittance (Y_m).

Where each term can be define and calculated as follow:

2.1. Line Parameters

Characteristic impedance could be calculated by:

$$Z_c = \frac{\eta_0}{\sqrt{\varepsilon_e}} \frac{h}{W_e}$$

where

$$W_e = \frac{W + W_c}{2}$$

2.2. Self Admittance

In order to determine $Y_s(= G_s + jB_s)$, previous works for rectangular microstrip antennas have been examined for improving the accuracy and efficiency of our model. In this respect Pues formula [1] is used for determining the self conductance G_s.

$$G_s = \frac{1}{\pi\eta}\{(wSi(w) + \frac{\sin w}{w} + \cos w - 2)(1 - \frac{s^2}{24}) + \frac{s^2}{12}(\frac{1}{3} + \frac{\cos w}{w^2} - \frac{\sin w}{w^3})\}$$

And for suseptance we used Pues formula [1] as given by:

$$B_s = Y_s \tan(\beta \Delta l)$$

Where the open end effect can be calculated as:

$$\frac{\Delta l}{h} = 0.412 \frac{\varepsilon_e + 0.300}{\varepsilon_e - 0.258} \frac{W_e/h + 0.262}{W_e/h + 0.813}$$

2.3. Mutual Admittance

Accurate closed-form expressions have been derived for both the real and imaginary parts of mutual admittance $Y_m = G_m + jB_m$ for rectangular microstrip antenna by Pues [1]. In order to determine the Mutual admittance we used the Pues formula as follow:

$$G_m = K_g F_g G_s$$

where

$$K_g \approx 1$$

$$F_g \approx J_0(l) + \frac{s^2}{24 - s^2} J_2(l)$$

and

$$B_m = K_b F_b B_s$$

where

$$F_b = \frac{b_m}{b_s} \approx \frac{\pi}{2} \frac{Y_0(l) + \frac{s^2}{24 - s^2} Y_2(l)}{\ln(\frac{s}{2}) + C_e - \frac{3}{2} + \frac{s^2/12}{24 - s^2}}$$

$$k_b = 1 - \exp(-0.21w)$$

3. Results

For different flare angle of bowtie patch antenna we calculated the antenna parameters as stated above then we compared results of return loss obtained from the purposed model with results obtained by Advanced Design System where uses MoM.

As seen in Fig. 5 good agreement have been achieved for different flare angles. Also the error between the two methods increase by increasing flare angle from 3% for $\alpha = 10^o$ to 5% for $\alpha = 30^o$. For small flare angle the results of purposed model have good agreements with full wave results, but as the flare angle increased the results are not in good agreement because of radiations from side slots. As this radiations are more effective in higher flare angle so for large flare angle this model are not valid anymore.

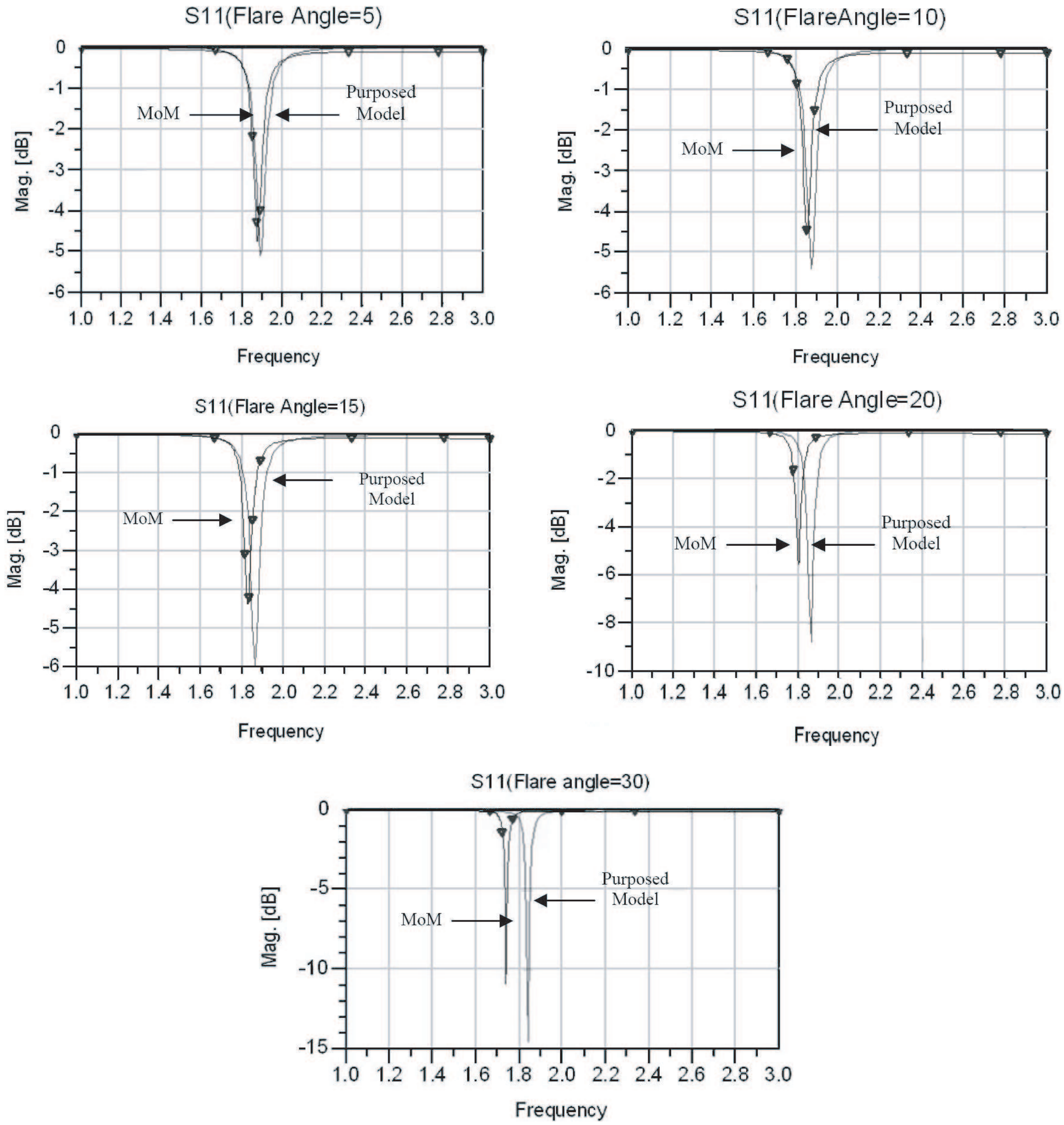

Figure 5: Return Loss for different flare angles.
$\varepsilon = 4.4$, $h = 1.6\,\mathrm{mm}$, $L = 18.75\,\mathrm{mm}$, $W = 25.2\,\mathrm{mm}$

4. Conclusion

A novel transmission line model is represented for modeling the bowtie patch antennas. Admittance and controlled source equations used in the passed for rectangular patch antennas have been modified in this model for bowtie patch antenna. This model is just valid for a moderate range of flare angles and results are reasonably accurate in that region and therefore this approach can be used as TLM for bowtie patch antenna for evaluating antenna parameters.

Acknowledgement

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